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A HISTORY OF COST-EFFECTIVENESS

E. S. Quade\*

The Rand Corporation, Santa Monica, California

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The practice of cost-effectiveness started when man first realized his resources were limited. For one Congressional Committee, this took place in the Garden of Eden with the decision to eat or not to eat the apple. They noted that: "the problem from the outset has been to avoid an underestimation of the costs and an overestimation of the benefits" [1]. But cost-effectiveness did not become an organized activity, did not attract much attention in the literature of decisionmaking, and did not get the name until after World War II. It has really blossomed since then; in 1969 for instance, the U.S. Senate held closed sessions with as many as 95 senators present to listen to and debate the merits of detailed cost-effectiveness analyses on the Safeguard program. It has also acquired some bitter critics.

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We all practice cost-effectiveness: from the housewife who attempts to run her household on a fixed budget to the public utility that must choose between nuclear energy and fossile fuel. This paper presents a personal and thus a distorted history of the formal or institutionalized practice of cost and effectiveness comparisons, of the sort that both public and private organizations employ to aid managers and decisionmakers.

For this paper, let me provide working definitions. Cost-effectiveness analysis and cost-benefit analysis, together with systems analysis, policy analysis, operations research, management science and other decision disciplines, seek to provide advice, to help ~~someone make a decision~~. Cost-effectiveness attempts to do this by comparing various actions that might be taken in terms of their costs and their effectiveness in achieving a desired goal. The costs--properly the opportunities foregone--are ordinarily represented more or less satisfactorily in monetary units. Effectiveness presents more of a problem. In the usual analysis, the benefits--that is to say, the gains made in achieving the goal--are measured on a scale which is allowed to depend on the nature of the particular goal. Thus, while we may be able to use cost-effectiveness to decide between competing alternatives for the same goal, we cannot use it to compare different tasks--to decide, say, the best overall use for our money. That requires something more; namely, that the effectiveness be measured in the

same units as the costs, so that the difference between the benefits and the costs can be calculated and compared with that difference for other possible actions. When this is done, we have a specialized form of cost-effectiveness analysis that we call cost-benefit analysis. It is a much more powerful tool for decisionmaking, but much more limited in application for it is far harder to perform satisfactorily.

This Federation, if it were to take an official position, would not, I believe, distinguish between cost-effectiveness and the various other advisory and managerial disciplines. I base this assertion on the report of the Working Group on Cost/Effectiveness that met in Venice at the 1969 IFORS Conference. Let me quote the last two sentences from that report.

"A considerable amount of discussion concerned a serious attempt to find any real differences between the general practice of OR and of cost-effectiveness. The discussants failed to find a single real differentiating criterion between the two practices and agreed that, in essence, the difference was a matter of emphasis" [2].

### PRECURSORS

While the term cost-effectiveness did not become popular until very recently, cost-effectiveness thinking has long been practiced. Let me illustrate with some early instances that I found interesting. All have a modern touch.

The first is from the Far East. At the beginning of the 11th Century when China was under the reign of the Sung Dynasty, the palace buildings in the capital, Pientu (today Kaifeng, Honan Province), burned down. The Emperor ordered his chief engineer, Ting Wei, to direct the construction of a new fireproof palace. It was an enormous undertaking. The materials had to be transported to the worksite from a considerable distance outside the city. The traditional alternatives were to use men shouldering carrying-poles or animals pulling carts. In either case a tremendous amount of manpower was needed. To cope with this situation, Ting Wei devised a far more ingenious and cost-effective method. He had the workers dig up the earth of the wide street right by the worksite. The ditch so formed was extended to the Pien River outside the city. Boats bringing building materials could then sail right up to the job. As the work neared completion, Ting Wei ordered the labourers to fill up the ditch with brick and tile scraps, leftover earth, and waste. The ditch became a street again [3].

Consider, as a second example of cost-effectiveness analysis, the effort by Benjamin Thompson, Count Rumford, to improve and to lower the cost of clothing for the Bavarian Army. To determine the most efficient clothing material, he performed experiments on the thermal conductivity of cloth, leading to his discovery of convection currents and of the insulating value of air trapped between layers of cloth. Unfortunately, he was not able to convince the suppliers that they should change their product. He then established his own factory. It was not successful, however, due to opposition by the established industrialists [4].

A third example appears in the Report of the Board on Fortifications and Other Defenses, U.S. War Department, 1886 [5]. Two types of 12-inch breech loading rifles were under consideration by the War Department for use by the Coast Artillery for coast defense. One was a steel Krupp-type rifle of then standard design and the other was a new U.S. development of cast-iron. To help in the choice, an analysis based on actual performance tests and manufacturing costs had been carried out. This showed the ratio of effectiveness to cost for the steel gun to be only 0.8 of that for the new cast-iron gun. The measure of effectiveness was the "power" of the gun, the energy at the muzzle expressed in foot-tons. This first analysis did not fully satisfy the Board and further analysis was ordered.

The following statement from the Report describes that analysis. Let me quote:

"By virtue of certain well-established principles in gunnery, relative to the similitude of guns, with similarity of loading, it is easy to deduce the caliber and weight of a piece, of either of the above types, which shall possess a given power, or which shall have the same power, for instance, as a piece of the other type. In this way we may reduce our data to the same absolute standard, and thus give the analysis a strictly quantitative character."

When the analysis was carried out, the cast-iron gun that would produce the same muzzle energy as the steel gun turned out to cost only 0.8 as much as the steel gun. Furthermore, when a Krupp-type gun with the same muzzle energy as the cast-iron gun was designed and costed, it turned out to cost about 20% more than the cast-iron gun.

The Board then made an emphatic decision--they recommended steel. Let me quote a few of the arguments as given in the Report--somehow they sound familiar:

"...we have no evidence touching the endurance of cast-iron guns..."

"...the difference in cost is not great, particularly when it is remembered that cheapness is the chief merit claimed for cast-iron..."

"...their production in quantity...will unquestionably delay the development of the steel industry of this country..."

"It would be singular if, after waiting for so many years with the alleged intention of profiting by the experience of nations foremost in the

manufacture of heavy ordnance, we should begin the long-neglected defense of the country with accepting a material for guns which, after having been tried by leading European nations, have been deliberately rejected in favor of steel."

About the same time, the first treatise on cost-effectiveness of which I'm aware appeared. It was a 980-page volume by A. M. Wellington entitled: The Economic Theory of the Location of Railways, first edition 1887. For him, engineering required one to do more than to make the properties of matter and the sources of energy in nature useful to man. Let me quote:

"It would be well if engineering were less generally thought of, and even defined, as the art of constructing. In a certain important sense it is rather the art of not constructing; or, to define it rudely but not inaptly, it is the art of doing that well with one dollar, which any bungler can do with two after a fashion" [6].



### MODERN DEVELOPMENT

Cost-effectiveness analysis as we know it today represents the confluence of three streams of development. These originated, respectively, in economic theory, in practical engineering, and in the operational analysis of World War II. Earlier instances, such as those mentioned earlier, were isolated and, as far as I can determine, did not affect these streams. For example, Wellington, now quoted in current textbooks on engineering economics, was unmentioned in 1950 and earlier editions.

The systematic analysis of investment alternatives from the point of view of a government had its start, according to one source [7], in economic theory with the works [8] of a Frenchman, Jules Dupuit. He recognized that the benefits to the community resulting from public enterprises like bridges and roads are likely to be much more than the revenues generated to the public treasury through actual payments by the public of tolls and taxes. Others [9] cite the origin as late as the 20th Century with the Cambridge economist, A. C. Pigou.

Economists, however, did not pay much attention to cost-effectiveness and cost-benefit analysis until the 1950's. For instance, even though they made no attempt at completeness, it is interesting that, out of a bibliography of 90 items, Prest and Turvey in their excellent survey of cost-benefit analysis cite only three items published before 1950 [10]. The spur to economic interest seems

to have been the expansion of public investment activity in the United States, especially in water-resources development, during the 1930's.

The first systematic attempt to apply cost-benefit analysis to government economic decisions probably started in the United States. Here it was a matter of practical engineering, with the attempt, starting about 1900, to improve harbor and river navigation. Here it was "in origin an administrative device owing nothing to economic theory" [11].

The River and Harbor Act of 1902 required that a board of engineers review the desirability of river and harbor projects proposed by the Army Corps of Engineers with respect to their costs and to the commerce benefited. Since local interests usually received extra benefits, it seemed they should also be charged with part of the costs. To do this, the Corps of Engineers worked out techniques for determining the dollar value of the more obvious benefits.

Later, the Flood Control Act of 1936 specified that Federal participation in flood control schemes could take place only "if the benefits to whomsoever they may accrue are in excess of the estimated costs." Subsequently, analysis designed to prove that this standard was being met accompanied each proposal by the Corps of Engineers. The practice spread to other agencies concerned with water-development projects; for example, the Bureau of

Reclamation (Interior Department). The purpose was to some extent for project planning and to decide how much local interests should pay, but mainly it "served as window dressing for projects where plans were already formulated with little, if any, reference to economic criteria" [7, p. 18].

Since the 1936 act did not specify the criteria by which benefits and costs were to be measured, the various agencies developed their own--biased toward their own programs. In 1950 an interagency committee produced the "Green Book" [12], in an attempt to introduce uniformity. It never obtained official standing, however. The Bureau of the Budget got into the act because it reviews proposals for project authorization and requests for appropriations before transmission from the Executive to Congress and, in 1952 [13], and later in 1961 [14], developed its own set of criteria. These were much criticized for their restrictive nature and a new interagency committee, the President's Water Resources Council, made recommendations in 1962 [15] which, insofar as I know, are still the U.S. Government standard.

The third line of development started after World War II, when wartime operational analysis grew first into operations research and then into systems analysis. Application of these disciplines to military development and procurement problems introduced cost-effectiveness

analysis to government decisionmaking from a second source. The cost-effectiveness analysis that developed in this way, however, did not become cost-benefit analysis; attention was focused on the question which of a restricted class of alternatives was best, rather than on the more complex question of whether the task being considered was worth performing at all, since the resources required would have to be drawn from other uses. Analysts dealt with the question of what is the least costly program to achieve a given goal--say, of five proposals in an all-weather fighter competition, which, for a fixed budget, would be the most effective. The question of whether a new fighter should be developed at all just didn't come up very often in those days of expanding military budgets. Also, effectiveness was difficult enough to quantify on any scale, let alone on a monetary one.

Cost-effectiveness, as we know it in operations research, developed largely through this route. In fact, I believe, but again on very personal evidence, that very few operations research workers in this country were aware of cost-benefit analysis based on economic theory or even of its development in the water resources context. This was true in my own experience. It wasn't until Armen Alchian, Jack Hirshleifer, and other economists tore my first system study apart that I became aware that economic theory had anything much to contribute to weapon choice.

Certainly there is little or nothing in the early literature of operations research to indicate otherwise, and very little about cost-effectiveness itself. Around the late 1950's when Roland McKean's Efficiency in Government Through Systems Analysis [16], appeared under the sponsorship of Rand and the Operations Research Society of America, this had begun to change.

Although cost-effectiveness and cost-benefit analysis did not emerge as recognized disciplines until fairly recently, they have grown rapidly in the past few years. A check of the new cumulative index reveals that the first article indexed under cost-effectiveness appeared in Operations Research in 1955 [17]; the second in 1964; but by 1966 there were five articles. Until 1964, I could find no articles on either topic in the index or table of contents of the Operational Research Quarterly. Out of the first 9000 abstracts in the International Abstracts in Operations Research only something like four were indexed under cost-effectiveness. Until the fifth meeting of IFORS in 1969, I could find no mention of cost-effectiveness in its proceedings.

As for the societies themselves, the Cost-Effectiveness Section of ORSA was not established until 1965; the Special Study Group for Cost-Effectiveness by the Operational Research Society was announced about three years later.

In the United States, the great boost to cost-effectiveness came when Charles Hitch, appointed Assistant Secretary

of Defense (Comptroller) under Robert S. McNamara, brought to the Department of Defense both new ways of thinking about defense problems and a group of analysts and economists to apply them. This boost was followed a few years later (1965) with a boost for cost-benefit analysis when, pleased with the results in the DoD, President Johnson directed that the PPBS activity be extended throughout the federal government. The implementing memorandum from the Bureau of the Budget directed that analysis comparing the benefits and costs of alternative programs be carried out before budget approval could be obtained.

### METHODOLOGICAL DEVELOPMENT

If we contrast the cost-benefit analysis of the 1930's and the cost-effectiveness analysis of the 1950's with the best practices today, we can see that time has brought about considerable improvement. Nevertheless, displeasure with, and criticism of, the way cost and effectiveness are used to help make decisions has not disappeared.

The first thorough published criticism of the discipline itself (with suggestions for improvement) may have been that of Roland McKean in his 1958 book [16]. Many of McKean's concerns have by now largely vanished from the better analyses. The pitfalls that he saw in the use of ratios, in inappropriate criteria, in the failure to take proper account of the time-stream of future costs are now largely seen by all practitioners. For example, we have largely ceased to write C/E. This does not mean that there is no room for improvement.

Can we make cost-effectiveness and cost-benefit analysis better? In theory, we certainly can. For example, there is a need to treat the externalities explicitly and fully--to look for the negative spillovers--pollution et al, as well as to search out every benefit. Conceptually, we may be able to do this. Also we should be able to find ways to take into account the distributional aspects of both costs and benefits, for the one who pays the costs may not be the one who reaps the benefits.

Not that he always should but there ought to be a way to trace any transfer payments, to see that they go to the people that are supposed to benefit. The Flood Control Act of 1936, for example, was concerned only that the benefits exceeded the costs "to whomsoever they may accrue." These are not easy problems in practice, however.

One improvement would lie in a more thorough treatment of the social opportunity costs. For decisions involving public money, shouldn't we really be looking for the best alternative use to which the given resources can be put? In the usual cost-benefit analysis, for a given project, we seek to maximize the present value of all benefits less that of all costs. The ideal study would compare the sum of the benefits for the project under investigation with those of the best other project that might be carried out with the given dollars. In other words, if we didn't do a particular project, could the money be spent for a project that would yield even greater benefits? There are, of course, practical constraints. Money must be spent legally, for instance, and the original sponsors are unlikely to countenance a lesser benefit for themselves.

Another cost that should be explicitly considered is the implementation cost, including the cost of the organizational changes, if any, that need to be made if a new program B is to supplant ongoing program A. Almost always there are problems with organizations and some



individuals attendant to the use of analysis. It is more than resistance to the changes in practices that will ordinarily be required, for the use of analysis may itself affect the implementing bureaucracy in a serious way--for instance, by changing the power relationships, impairing incentives, or showing a tendency to increase centralization. One aspect of a cost-benefit analysis should thus include explicit discussion and evaluation of the implementation and organizational costs (and possibly benefits) associated with each alternative.

New methods of analysis may be needed. Two approaches appear particularly promising to me. One is n-person game theory. For problems that can be quantified satisfactorily, this may provide a way for dealing with the externalities and other difficult-to-handle aspects of economic systems [18]. Another is to use techniques for the systematic application of group judgment and intuition; for instance, Delphi [19, 20]. Without an approach such as Delphi, we have no systematic way of investigating aspects of a problem where quantification is beyond our capabilities. Delphi provides a way to take account of the social costs and benefits; for example, those involved in evaluating a project's impact on the range of individual choice or the probability of maintaining individual rights.

CONCLUDING REMARKS

Cost-effectiveness and cost-benefit analysis have spread rapidly in the few years since program budgeting was introduced into the U.S. Defense Department. In this country, their practice is widespread throughout federal, state, and local governments. It is well established abroad. Nevertheless, I regard its acceptance in an environment populated with politicians as remarkable--for politics is geared to winning the voters by outlining the benefits of programs before the means and the costs are determined.

Let me say a few words about the criticism. It is as often for what cost-effectiveness is not as for what it is. Sometimes the criticism may go so far as to imply that such analysis can never be done properly and that, even if it could, it is certain to have disastrous consequences. Thus:

"One of the prime obstacles to adequate defense weapons and measures in recent years has been a hurdle called cost-effectiveness. This test applied by scientists and theorists has killed off many new weapons, urgently requested by military leaders.

The man who gets credit for introducing the cost-effectiveness test for weapons is Charles J. Hitch, assistant secretary of defense, comptroller. He has recently resigned and is reported soon to be the financial manager of the University of California.

If Hitch applies cost-effectiveness to the curriculum at California, philosophy will have to go. It does not give the financial return to graduates which they can get from medicine,

engineering or law. The department of education no doubt will be eliminated also. Teaching does not pay as well as dentistry.

If we continue to eliminate or delay needed weapon developments because they cost too much, communism will win. The Reds do not have their eyes on the cash register, but on victory" [21].

Some criticism may also admit that cost-effectiveness is not totally deficient but suffers largely from the inadequacies and biases of its practitioners.

The cost-effectiveness people have created the illusion that they are capable of relating cost to military effectiveness by scientific analysis. In actual fact, they are just as reluctant to change preconceived opinions as they accuse the military of being....

The basis for using cost-effectiveness studies as the rationale on which to make a decision is the assumption that the important factors can be expressed in numerical form and that a correct judgment of the situation can then be calculated mathematically. But for most complex situations this is an unrealistic assumption....

...Far more emphasis has been placed on determining the cost than on studying the military effectiveness. All factors of military effectiveness for which the analyst cannot calculate a numerical value have automatically been discarded from consideration....

Cost effectiveness analyses may be helpful in arriving at an answer if their limitations are understood and if they are used properly [22].

Prest and Turvey put it well:

"...one can view cost-benefit analysis as anything from an infallible means of reaching the new Utopia to a waste of resources in measuring the unmeasurable" [10].

How does the future look? The nature of public activities are such that accomplishments and benefits in relation to cost often cannot be precisely measured even after the fact. Hence cost-effectiveness and cost-benefit analysis cannot yet be regarded as devices to provide definite and objective conclusions. But they can provide partial answers and serve as pedagogical and intuition reinforcing tools. Thus, for those of us who believe that partial analysis is far better than no analysis, their future looks bright indeed.

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